Fiber Optics

solving the mystery

by Capt. Michael P. Roddy

During the last two decades a number of technological breakthroughs have made possible a rapidly growing communications medium known as fiber optics. As with most new technologies we tend to ignore and avoid them because we do not understand them. This article, therefore, will take some of the mystery out of fiber optics as well as explain some of its advantages and disadvantages.

A fiber optic system is composed of that equipment which fits between the final multiplexer and initial demultiplexer. Most of the fiber optic systems in use today are used as substitutes for copper cable in major telephone trunking systems. Put simply, the I.F. (Intermediate Frequency) electrical signal is converted into an electrical impulse which in turn switches a light source on or off. This is done thousands of times a second. The light travels down an optical fiber which is about the size of a human hair. At the opposite end of the fiber, a detector decides whether the light source is on or off. The signal is then re-converted into an electrical signal, amplified, and sent to the demultiplexing equipment.

Current fiber optic systems have a number of advantages over conventional copper cable systems. The most notable are:

Small size and light weight. A fiber the size of a human hair can carry the equivalent of 8000 voice frequency conversations. A one-kilometer reel with 48 separate fibers weighs about the same as a 1/4 mile reel of CX-11230. Estimates suggest that where used in the B-1 bomber, fiber optics will save 370 lbs. over conventional copper cable.

Fiber optic cables have no electromagnetic signature and are nonconductive. This means that EMP (electromagnetic pulse) will not travel along a fiber the way it will down co-axial cable. Fiber optic cable can be operated next to high-voltage equipment and in high radiation environment without degrading the signal. One could wrap a cable around a 60k generator several times without affecting the signal.

Security. It is almost impossible to tap a fiber optic cable without being detected. A special meter looks down the fiber and can see any defects in the fiber. To tap the line someone would have to break into the hair-thin fiber.

Fewer repeaters are needed in fiber optics systems. Typical commercial systems can run 10 km between repeaters and experimental systems are running about 120 km without need for repeaters.

There are, however, some disadvantages with fiber optics:

First, fiber optics is an infant technology. The industry lacks standardization because of this newness. Also, there is a significant equipment cost involved in the transition to fiber optic interface equipment. Finally, field splicing will continue to be a problem. It is no longer a matter of resplicing the optical fiber, but rather a very time consuming process to fix the tension members and exterior cladding.

Let's talk about transmitter for a moment.

The function of the I.F.T. (Intermediate Frequency Interface) is to detect which logic state is evident on the I.F. during the sampling period. This may be as fast as every millionth of a second. The signal is then amplified and sent to the light source. Light sources come in two styles: LEDs (Light Emitting Diodes) or TILs (Transistor Injection Lasers). TILs are by far the most popular. These lasers are not the big, gas powered, metal melting lasers that come to mind when most people think of lasers. They are about the same size as a light emitting diode and are constructed the same way as integrated circuits. In fact LEDs and TILs are specialized integrated circuits.

Integrated circuits (IC's for short) are made from silicon to which impurities have been added. This causes the silicon to be more prone to give up or accept electrons depending on the "dopant." Two common dopants are gallium and arsenid. The area where the two "doped" types of silicon meet is called the p-n junction. If the silicon is doped with the proper materials, the p-n junction can be made to give off electromagnetic energy in the visible light spectrum. This is what is known as a light emitting diode. In special cases, the light can be resonated at the p-n junction so that all of the light has the same frequency or is said to be coherent. This source of coherent light is known as a laser. If one goes one more step and injects that light into a fiber optic cable, the result is known as a transistor injection laser (TIL). Turn it on or off depending on whether the digital signal is logic state 1 or 0, and you have a basic fiber optic transmitter.

That was the hard part. Let's skip the fiber optic cable for now and go to the other end where we find another p-n junction. The difference is that the materials for the receiver have been picked because the amount of light falling on the p-n junction causes the "bias" to change. In other words, the amount of current this diode will pass depends on the amount of light that is shining on it. The signal that is let through the diode is then amplified and sent out to be demodulated. It is either on or off at very high data rates.

The popular opinion exists that optical fibers, which are made of glass, are very fragile. This is not true. The individual fibers, each the size of a human hair, have such high tensile strength that most of us cannot pull them apart. The nearly pure glass from which typical fibers are made is flexible. An individual strand can be tied into a half-knot a 1/4 of an inch in diameter without permanently damaging the fiber. The two most common cables contain six or 48 hair-thin fibers.

Because of the way light travels down the inside of a fiber, the bend radius of full size cables should be limited to about a foot. It's probably impossible to tie the stuff around a duce-and-a-half bumper and tow a jeep with it. But no one said that fiber optic cable was indestructable.

There are two methods of connecting fibers. The first is mechanical. The second is to physically melt the fibers together. Epoxy glues and factory installed connectors have been developed which consistently show less than 1 dB of loss across the connection. This means that for three connections one could expect to lose 1/2 of the optical power (without a restorer). Melting the fibers can produce a flawless (no loss) joint with a great deal of consistency. An average experienced splicer can produce a splice which will only lose .2 dB per joint.

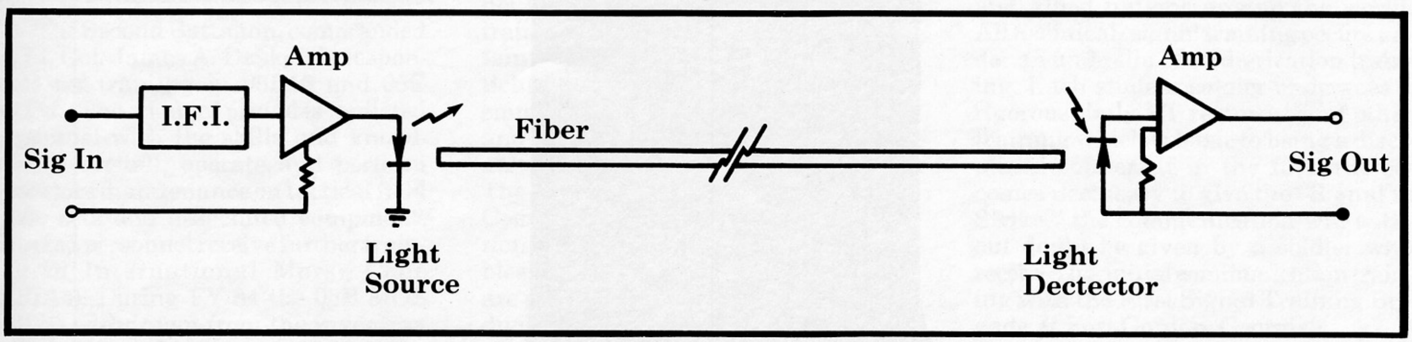
Fiber optic cable is made from a glass rod about an inch in diameter that has impurities added to the center to allow light, which bounces down the cable, to arrive at the same time as light that shoots straight down the middle. This is called a graded fiber and has become an industry standard. The rod is heated to its melting point at one end and a hair-thin fiber is pulled from it. The process, in fact, is similar to pulling taffey in that the resulting fiber though much smaller still has the same cross-sectional composition.

As one might guess, there's a lot of test equipment associated in the fiber optics. The granddaddy of it all is called an optical-time-domain-reflectometer (OTDR). Do not let the name scare you. Optical refers to visibility, as in the clarity of the fiber. Time-domain, as in radar, means a signal is sent down the fiber and any light coming back is measured against the time for the round trip. A reflectometer is simply a meter to measure the strength of reflected light.

The OTDR is based on a principle known as Rayliegh Backscattering which simply says that if a light beam hits any obstruction or imperfection in any medium, some of that light will be reflected back toward the source. The OTDR, therefore, allows us to keep a constant watch on the entire fiber optic system from end to end by watching this reflected light.

The future: Bell Laboratory ran a test on a new super laser last February. It passed 420 million bits a second over a cable 119 kilometers long without a repeater. Imagine 75 miles of CX-11230 without any TD-206's passing the equivalent of a 30 volume encyclopedia every second.

Fiber optics is an up and coming technology. Commercial trunking systems are already in use, and it is just a matter of time before we see it in the field.



Basic fiber optics system